CLAIMS:

1. A method for calculating the instantaneous phase in the respiratory cycle comprising at least the step of determining that if the instantaneous airflow is small and increasing fast, then it is close to start of inspiration, if the instantaneous airflow is large and steady, then it is close to mid-inspiration, if the instantaneous airflow is small and decreasing fast, then it is close to mid-expiration, if the instantaneous airflow is zero and steady, then it is during an end-expiratory pause, and airflow conditions intermediate between the above are associated with correspondingly intermediate phases.

2. A method for determining the instantaneous phase in the respiratory cycle as a continuous variable from 0 to 1 revolution, the method comprising the steps of:

selecting at least two identifiable features F_N of a prototype flow-vs-time waveform *f(t)* similar to an expected respiratory flow-vs-time waveform, and for each said feature:

determining by inspection the phase ϕ_N in the respiratory cycle for said feature, assigning a weight W_N to said phase,

defining a "magnitude" fuzzy set M_N whose membership function is a function of respiratory airflow, and a "rate of change" fuzzy set C_N, whose membership function is a function of the time derivative of respiratory airflow, chosen such that the fuzzy intersection M_N AND C_N will be larger for points on the generalized prototype respiratory waveform whose phase is closer to the said feature F_N than for points closer to all other selected features,

setting the fuzzy inference rule R_N for the selected feature F_N to be: *If flow is* M_N *and rate of change of flow is* C_N *then phase* = ϕ_N, *with weight* W_N.

measuring leak-corrected respiratory airflow,

for each feature F_N calculating fuzzy membership in fuzzy sets M_N and C_N,

for each feature F_N applying fuzzy inference rule R_N to determine the fuzzy extent $Y_N = M_N$ AND C_N to which the phase is ϕ_N, and

applying a defuzzification procedure using Y_N at phases ϕ_N and weights W_N to determine the instantaneous phase ϕ.

3. A method as claimed in claim 2, whereby the identifiable features include zero crossings, peaks, inflection points or plateaus of the prototype flow-vs-time waveform.

4. A method as claimed in claim 2, whereby said weights can be unity, or chosen to reflect the anticipated reliability of deduction of the particular feature.

5. A method as claimed in claim 2, in which the step of calculating respiratory airflow includes a low pass filtering step to reduce non-respiratory noise, in which the time constant of the low pass filter is an increasing function of an estimate of the length of the respiratory cycle.

6. A method as claimed in claim 2, in which the defuzzification step includes a correction for any phase delay introduced in the step of low pass filtering respiratory airflow.

7. A method for measuring the average respiratory rate, comprising the steps of:

determining leak-corrected respiratory airflow,

from the respiratory airflow, calculating the instantaneous phase ϕ in the respiratory cycle as a continuous variable from 0 to 1 revolution, calculating the instantaneous rate of change of phase $d\phi/dt$, and

calculating the average respiratory rate by low pass filtering said instantaneous rate of change of phase $d\phi/dt$.

8. A method as claimed in claim 7, whereby the instantaneous phase is determined by the method of claim 1 or claim 2.

9. A method for providing ventilatory assistance in a spontaneously breathing subject, comprising the steps, performed at repeated sampling intervals, of:

ascribing a desired waveform template function $\Pi(\phi)$, with domain 0 to 1 revolution and range 0 to 1,

calculating the instantaneous phase ϕ in the respiratory cycle as a continuous variable from 0 to 1 revolution,

selecting a desired pressure modulation amplitude A,

calculating a desired instantaneous delivery pressure as an end expiratory pressure plus the desired pressure modulation amplitude A multiplied by the value of the waveform template function $\Pi(\phi)$ at the said calculated phase ϕ, and

setting delivered pressure to subject to the desired delivery pressure.

10. A method as claimed in claim 9, whereby step of selecting a desired pressure modulation amplitude is a fixed amplitude.

11. A method as claimed in claim 9, whereby the step of selecting a desired pressure modulation amplitude in which said amplitude is equal to an elastance multiplied by an estimate of the subject's tidal volume.

12. A method for providing ventilatory assistance in a spontaneously breathing subject as described above, in which the step of selecting a desired pressure modulation amplitude comprises the substeps of:

specifying a typical respiratory rate giving a typical cycle time,

specifying a preset pressure modulation amplitude to apply at said typical respiratory rate,

calculating the observed respiratory rate giving an observed cycle time, and

calculating the desired amplitude of pressure modulation as said preset pressure modulation amplitude multiplied by said observed cycle time divided by the said specified cycle time.

13. A method for providing ventilatory assistance in a spontaneously breathing subject, including at least the step of determining the extent that the subject is adequately ventilated, to said extent the phase in the respiratory cycle is determined from the subject's respiratory airflow, but to the extent that the subject's ventilation is inadequate, the phase in the respiratory cycle is assumed to increase at a pre-set rate, and setting mask pressure as a function of said phase.

14. A method for providing ventilatory assistance in a spontaneously breathing subject, comprising the steps of: measuring respiratory airflow, determining the extent to which the instantaneous phase in the respiratory cycle can be determined from said airflow, to said extent determining said phase from said airflow but to the extent that the phase in the respiratory cycle cannot be accurately determined, the phase is assumed to increase at a preset rate, and delivering pressure as a function of said phase.

15. A method for calculating the instantaneous inspired volume of a subject, operable substantially without run-away under conditions of suddenly changing leak, the method comprising the steps of:

determining respiratory airflow approximately corrected for leak,

calculating an index J varying from 0 to 1 equal to the fuzzy extent to which said corrected respiratory airflow is large positive for longer than expected, or large negative for longer than expected,

identifying the start of inspiration, and

calculating the instantaneous inspired volume as the integral of said corrected respiratory airflow multiplied by the fuzzy negation of said index J with respect to time, from start of inspiration.

16. A method for providing ventilatory assistance in a spontaneously breathing subject, the method comprising the steps, performed at repeated sampling intervals, of:

determining respiratory airflow approximately corrected for leak,

calculating an index J varying from 0 to 1 equal to the fuzzy extent to which said respiratory airflow is large positive for longer than expected, or large negative for longer than expected,

calculating a modified airflow equal to said respiratory airflow multiplied by the fuzzy negation of said index J,

identifying the phase in the respiratory cycle,

calculating the instantaneous inspired volume as the integral of said modified airflow with respect to time, with the integral held at zero during the expiratory portion of the respiratory cycle,

calculating a desired instantaneous delivery pressure as a function at least of the said instantaneous inspired volume, and

setting delivered pressure to subject to the desired delivery pressure.

17. A method for providing ventilatory assistance in a spontaneously breathing subject, comprising the steps of:

determining respiratory airflow approxiamately corrected for leak,

calculating an index J varying from 0 to 1 equal to the fuzzy extent to which the respiratory airflow is large positive for longer than expected, or large negative for longer than expected,

identifying the phase in the respiratory cycle,

calculating a modified respiratory airflow equal to the respiratory airflow multiplied by the fuzzy negation of said index J,

calculating the instantaneous inspired volume as the integral of the modified airflow with respect to time, with the integral held at zero during the expiratory portion of the respiratory cycle,

calculating the desired instantaneous delivery pressure as an expiratory pressure plus a resistance multiplied by the instantaneous respiratory airflow plus a

nonlinear resistance multiplied by the respiratory airflow multiplied by the absolute value of the respiratory airflow plus an elastance multiplied by the said adjusted instantaneous inspired volume, and

setting delivered pressure to subject to the desired delivery pressure.

18. A method for providing assisted ventilation to match the subject's need, comprising the steps of:

describing a desired waveform template function $\Pi(\phi)$, with domain 0 to 1 revolution and range 0 to 1,

determining respiratory airflow approximately corrected for leak,

calculating an index J varying from 0 to 1 equal to the fuzzy extent to which the respiratory airflow is large positive for longer than expected, or large negative for longer than expected,

calculating J_{PEAK} equal to the recent peak of the index J,

calculating the instantaneous phase in the respiratory cycle,

calculating a desired amplitude of pressure modulation, chosen to servo-control the degree of ventilation to at least exceed a specified ventilation,

calculating a desired delivery pressure as an end expiratory pressure plus the calculated pressure modulation amplitude A multiplied by the value of the waveform template function $\Pi(\phi)$ at the said calculated phase ϕ, and

setting delivered pressure to subject to said desired instantaneous delivered pressure.

19. A method for providing assisted ventilation to match the subject's need, as claimed in claim 18, in which the step of calculating a desired amplitude of pressure modulation, chosen to servo-control the degree of ventilation to at least exceed a specified ventilation, comprises the steps of:

calculating a target airflow equal to twice the target ventilation divided by the target respiratory rate,

deriving an error term equal to the absolute value of the instantaneous low pass filtered respiratory airflow minus the target airflow, and

calculating the amplitude of pressure modulation as the integral of the error term multiplied by a gain, with the integral clipped to lie between zero and a maximum.

20. A method for providing assisted ventilation to match the subject's need, as claimed in claim 18, in which the step of calculating a desired amplitude of pressure modulation, chosen to servo-control the degree of ventilation to at least exceed a specified ventilation, comprises the following steps:

calculating a target airflow equal to twice the target ventilation divided by the target respiratory rate,

deriving an error term equal to the absolute value of the instantaneous low pass filtered respiratory airflow minus the target airflow,

calculating an uncorrected amplitude of pressure modulation as the integral of the error term multiplied by a gain, with the integral clipped to lie between zero and a maximum,

calculating the recent average of said amplitude as the low pass filtered amplitude, with a time constant of several times the length of a respiratory cycle, and

setting the actual amplitude of pressure modulation to equal the said low pass filtered amplitude multiplied by the recent peak jamming index J_{PEAK} plus the uncorrected amplitude multiplied by the fuzzy negation of J_{PEAK}.

21. A method for providing assisted ventilation to match the subject's need, and with particular application to subjects with varying respiratory mechanics, insufficient respiratory drive, abnormal chemoreceptor reflexes, hypoventilation syndromes, or Cheyne Stokes breathing, combined with the advantages of proportional assist ventilation adjusted for sudden changes in leak, comprising the steps, performed at repeated sampling intervals, of:

calculating the instantaneous mask pressure as claimed in claims 16 or 17,

calculating the instantaneous mask pressure as claimed in claim 18,

calculating a weighted average of the two pressures, and

setting the mask pressure to the said weighted average.